

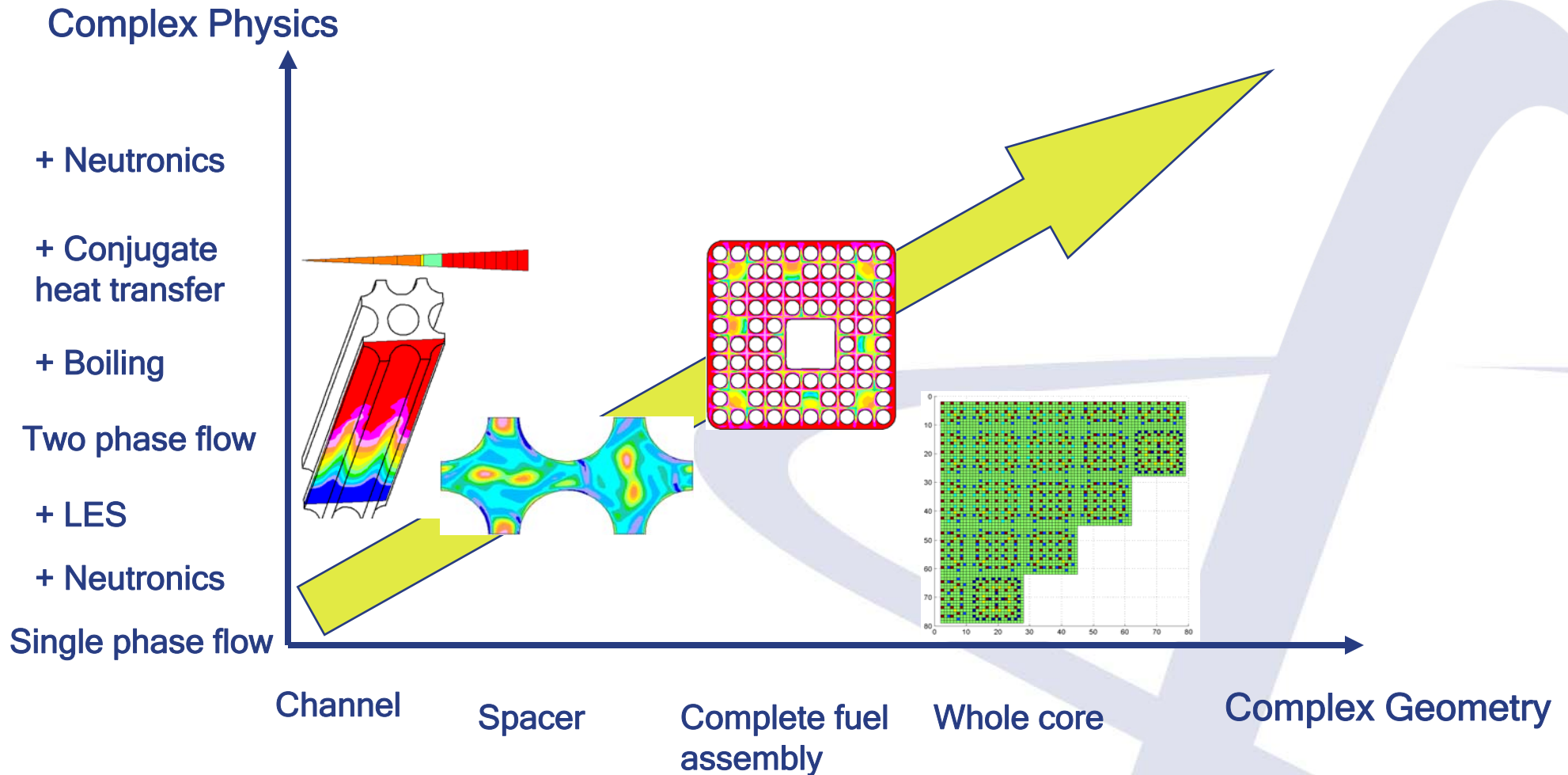
A high-speed photograph of a water droplet hitting a surface, creating a series of concentric ripples. The droplet is captured at the moment of impact, with a small crown-like shape forming at the point of contact. The background is a solid blue color.

High end computing for nuclear reactor simulations with  
STAR-CD

Simon Lo

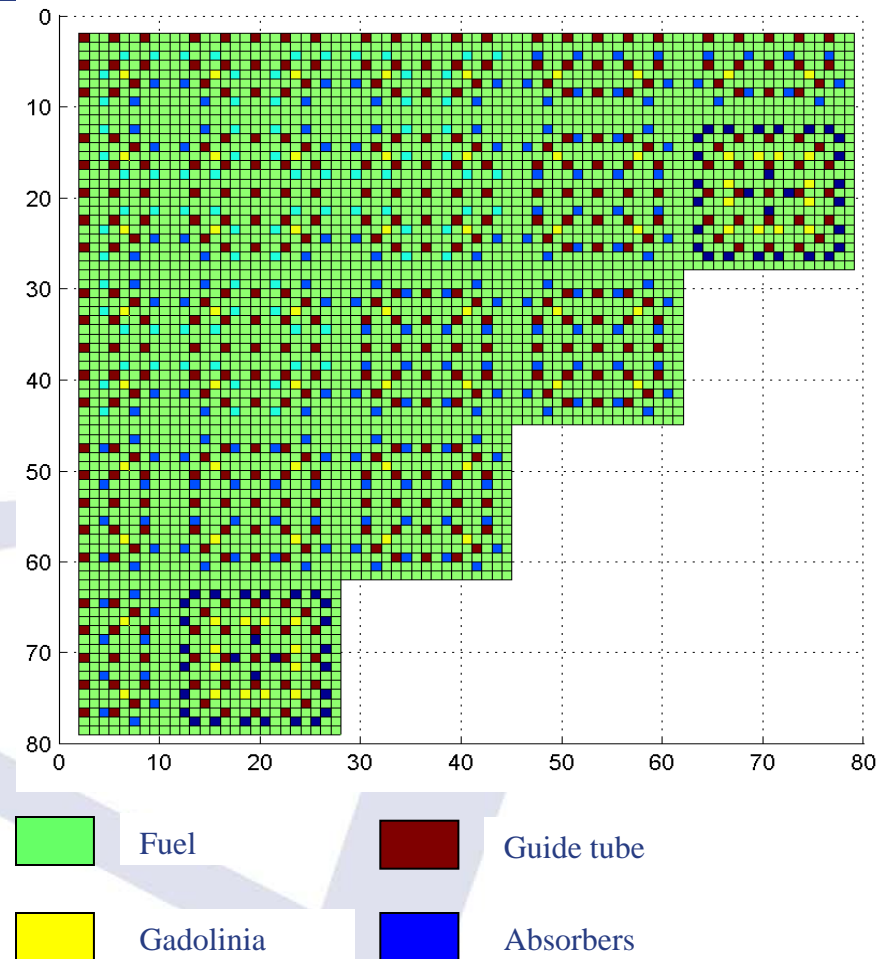
23 February 2006

# High end computing for Light Water Reactors



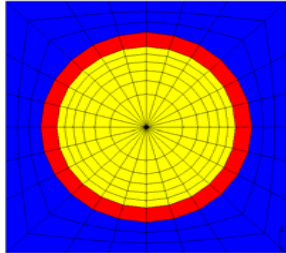
# Small PWR Core Configuration

- 3½ million flat flux regions in DeCART (1/4 core)
- 64 million cells in STAR-CD (1/8 core)
- ANL Beowulf cluster *jazz*:
  - 12 processors for DeCART
  - 57 processors for STAR-CD
  - 1 processor for the external interface
- Steady-state calculations required ~11 hours (not optimized)



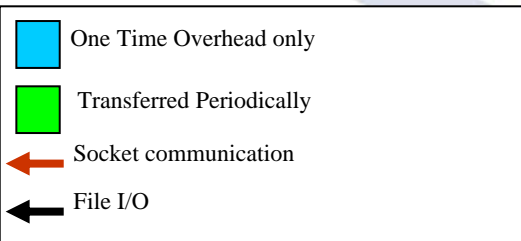
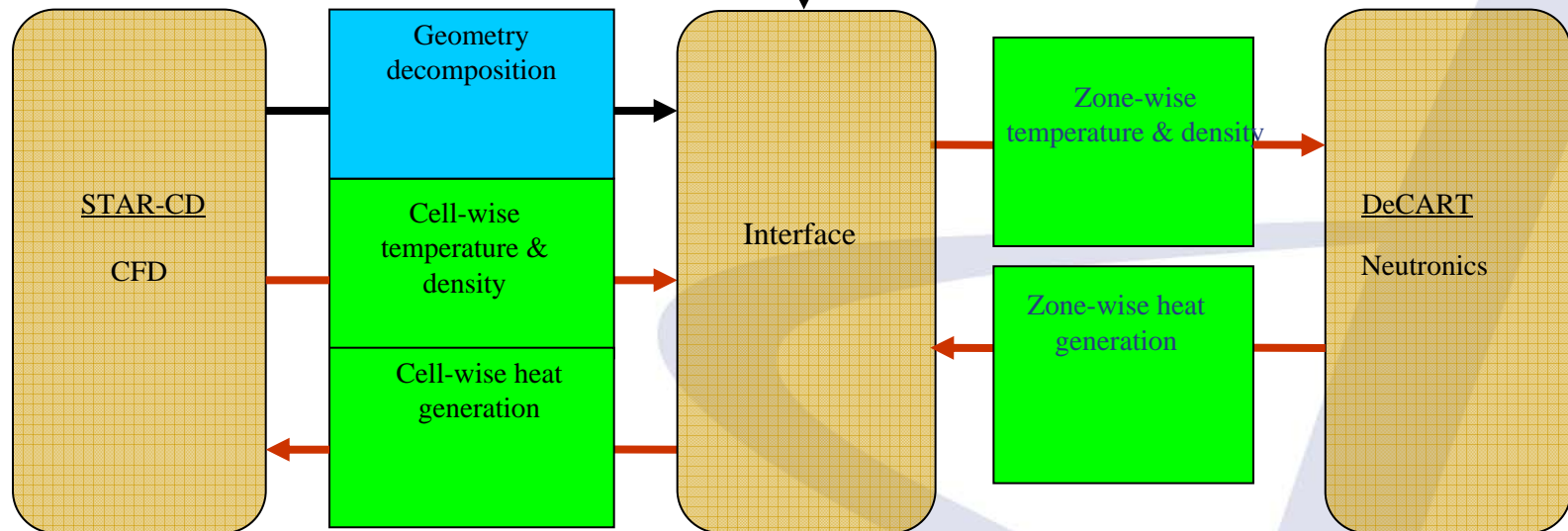
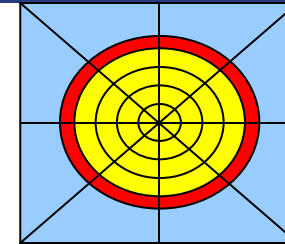
# Coupling Mechanics: Interface design

Typical  
STAR-CD pin  
mesh



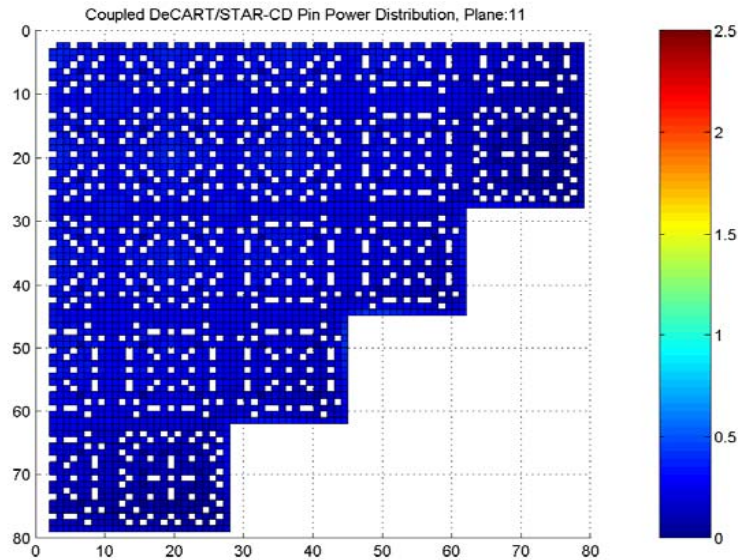
User Input

Typical  
DeCART pin  
mesh

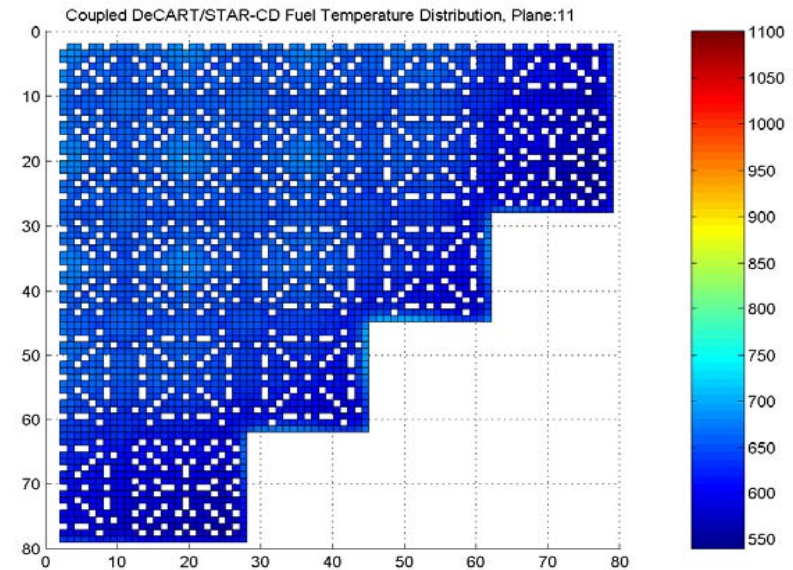


# Coupled Results: Temperature & Pin Power

Pin Power

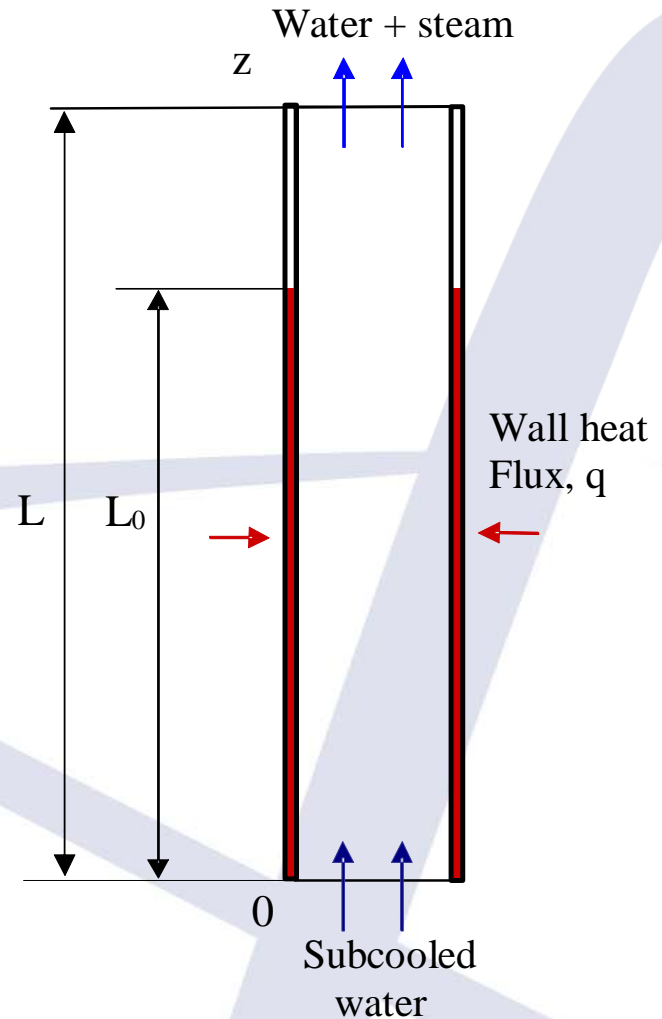
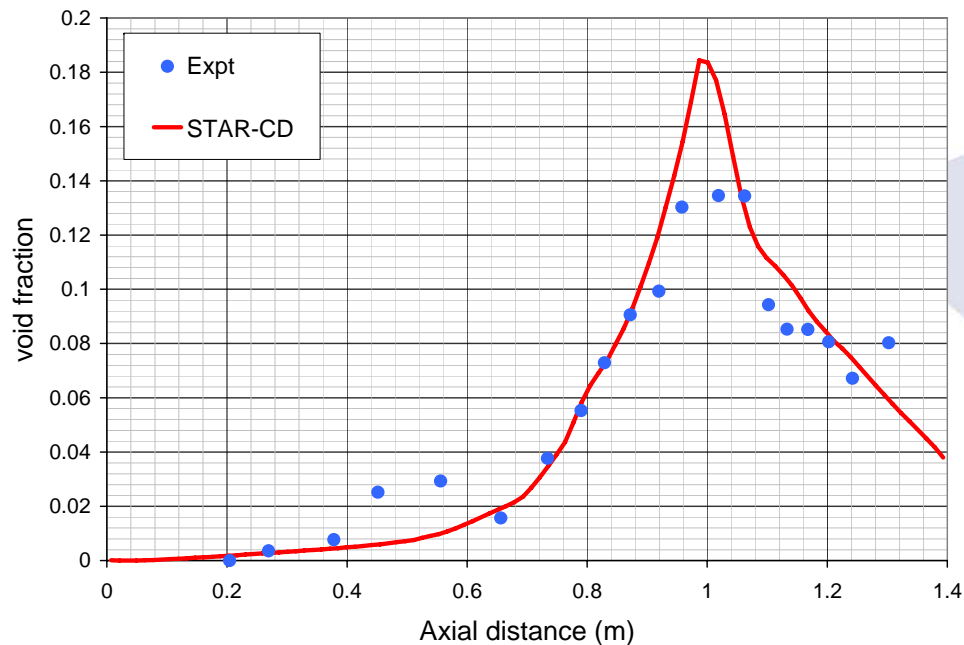


Avg. Fuel Temperature



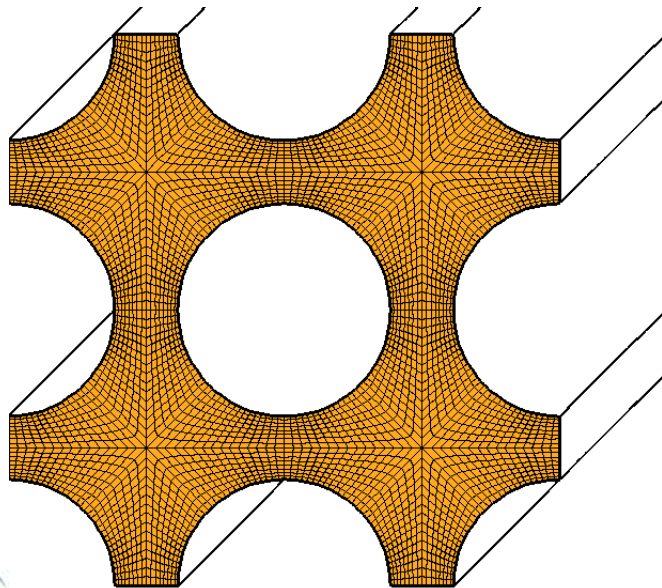
# Boiling two-phase flow

- Avdeev, Pekhterev & Bartolemei
  - Heat flux=1.2 MW/m<sup>2</sup>
  - Water flow rate=1500 kg/m<sup>2</sup>/s
  - Water sub-cooling=63 K

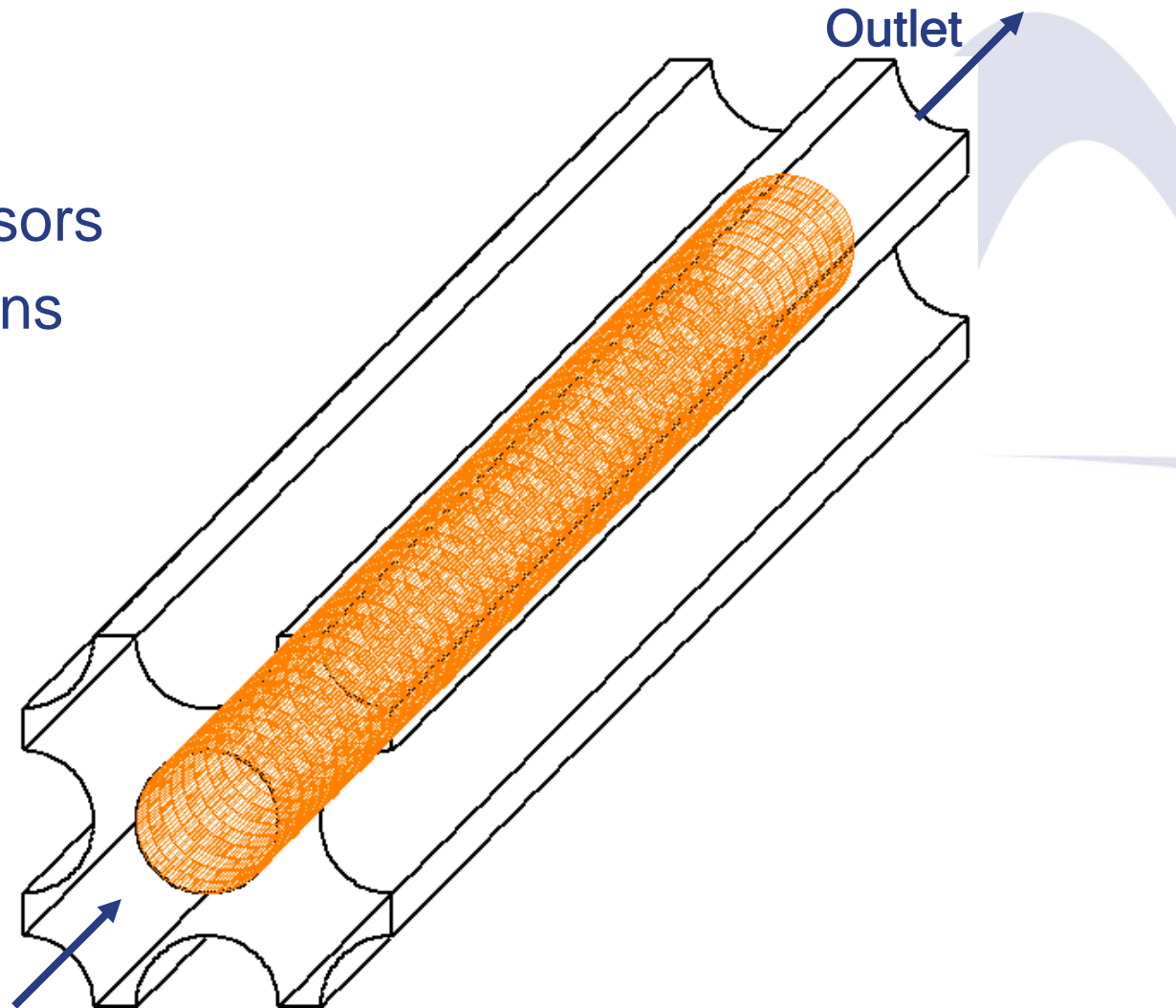


## 2 by 2 BWR channel model

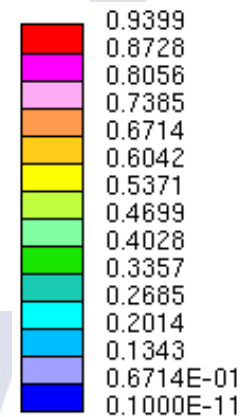
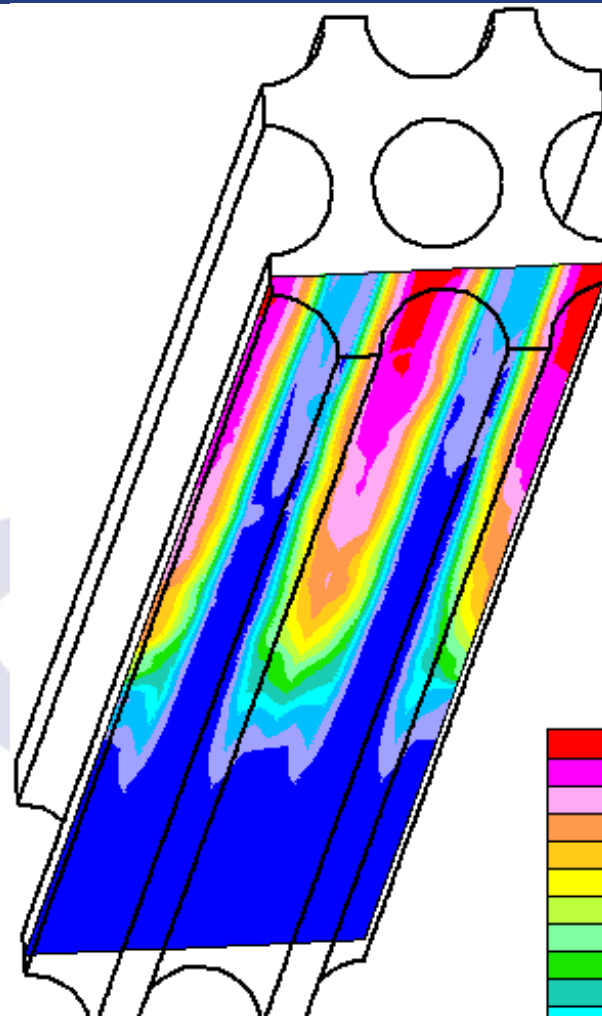
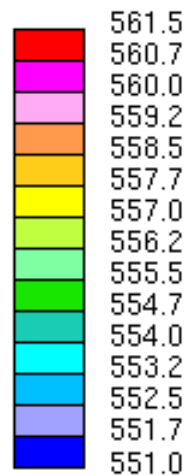
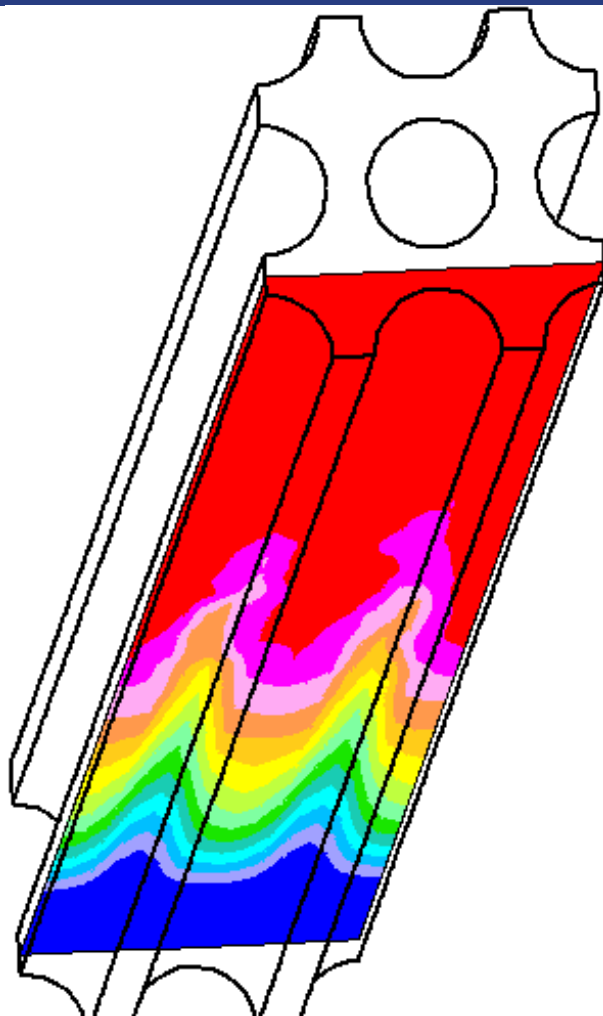
- ~150 k cells
- Boiling two-phase flow
- Linux pc with 2 processors
- Steady-state calculations required ~ 0.5 days



Inlet

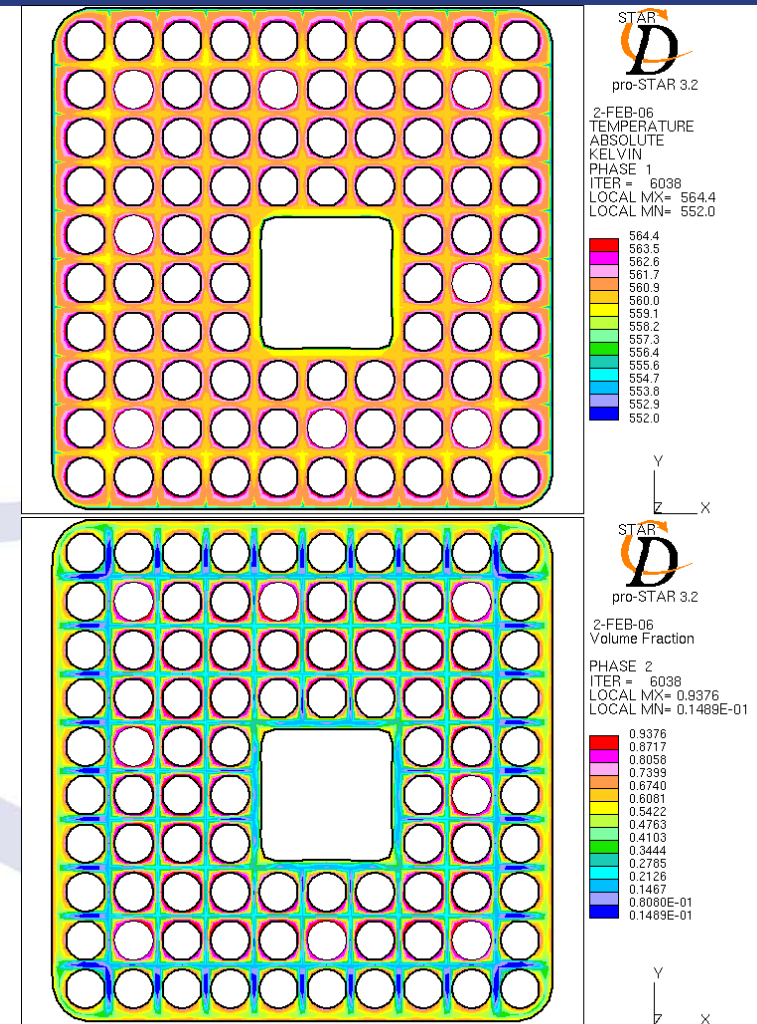


## 2 by 2 channel - Water temperature and void

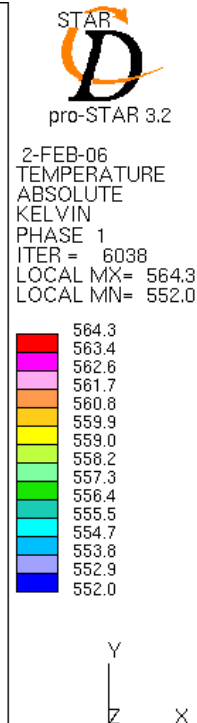
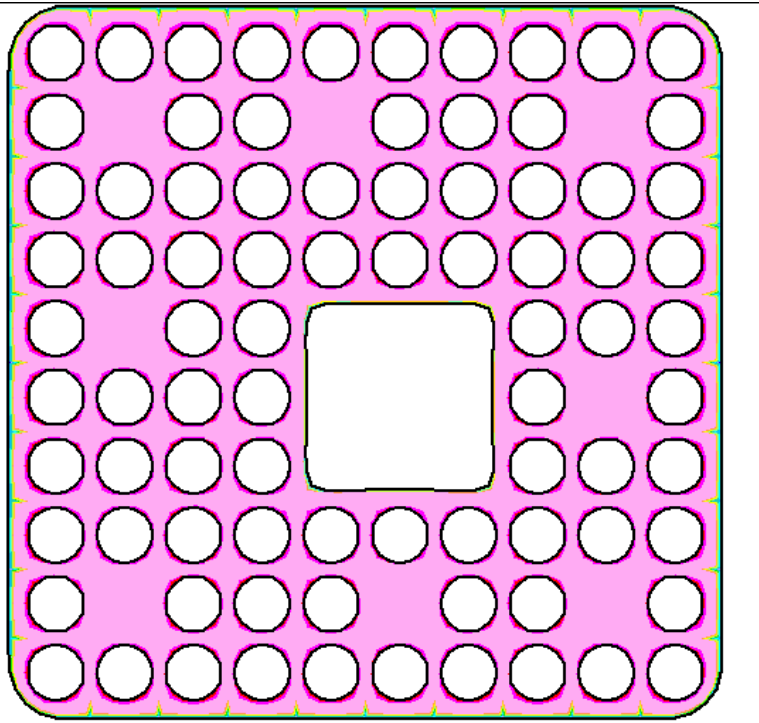


# Complete fuel assembly

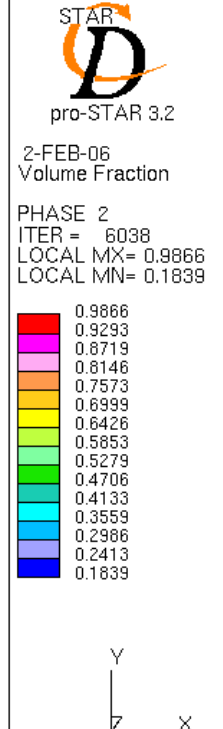
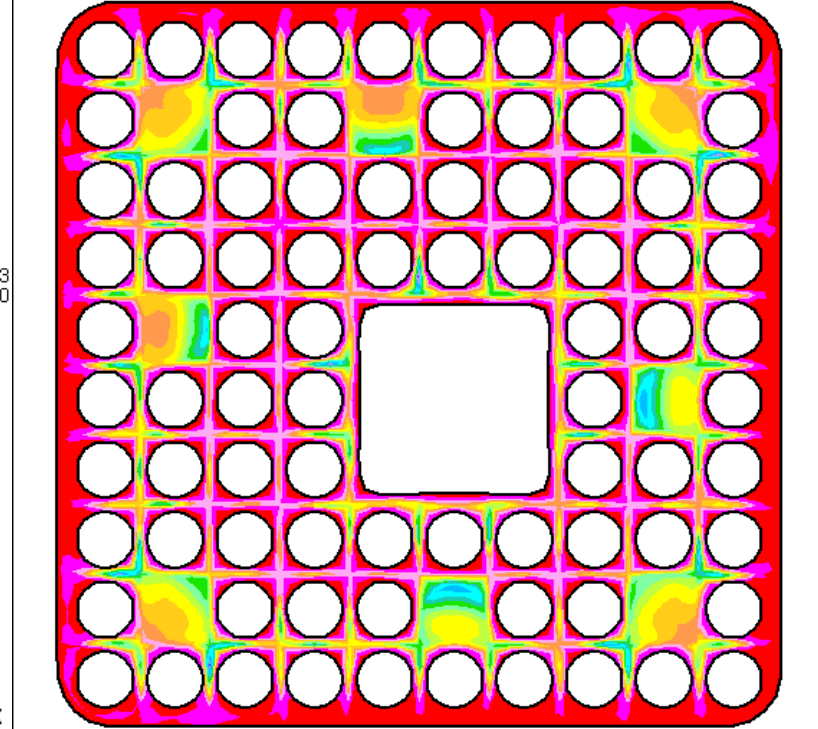
- ~1.5 M cells (coarse grid model)
- 10 by 10 fuel assembly, water channel, can wall
- Boiling two-phase flow
- Linux cluster: 10 processors
- Steady-state calculations required  
~1 day (not optimized)



# Complete fuel assembly – 3.8 m (top)



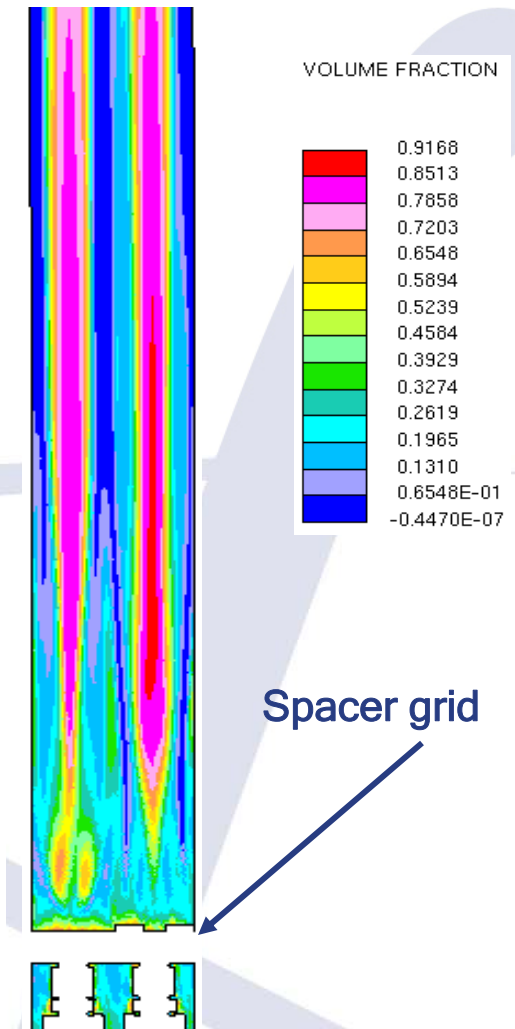
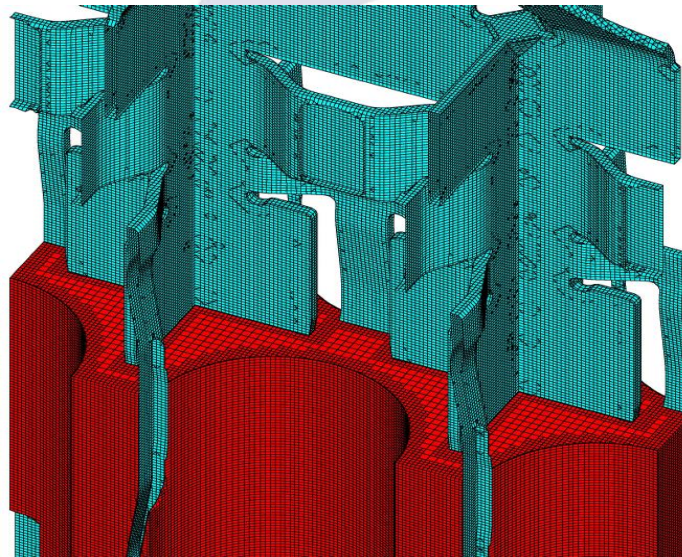
Water temperature



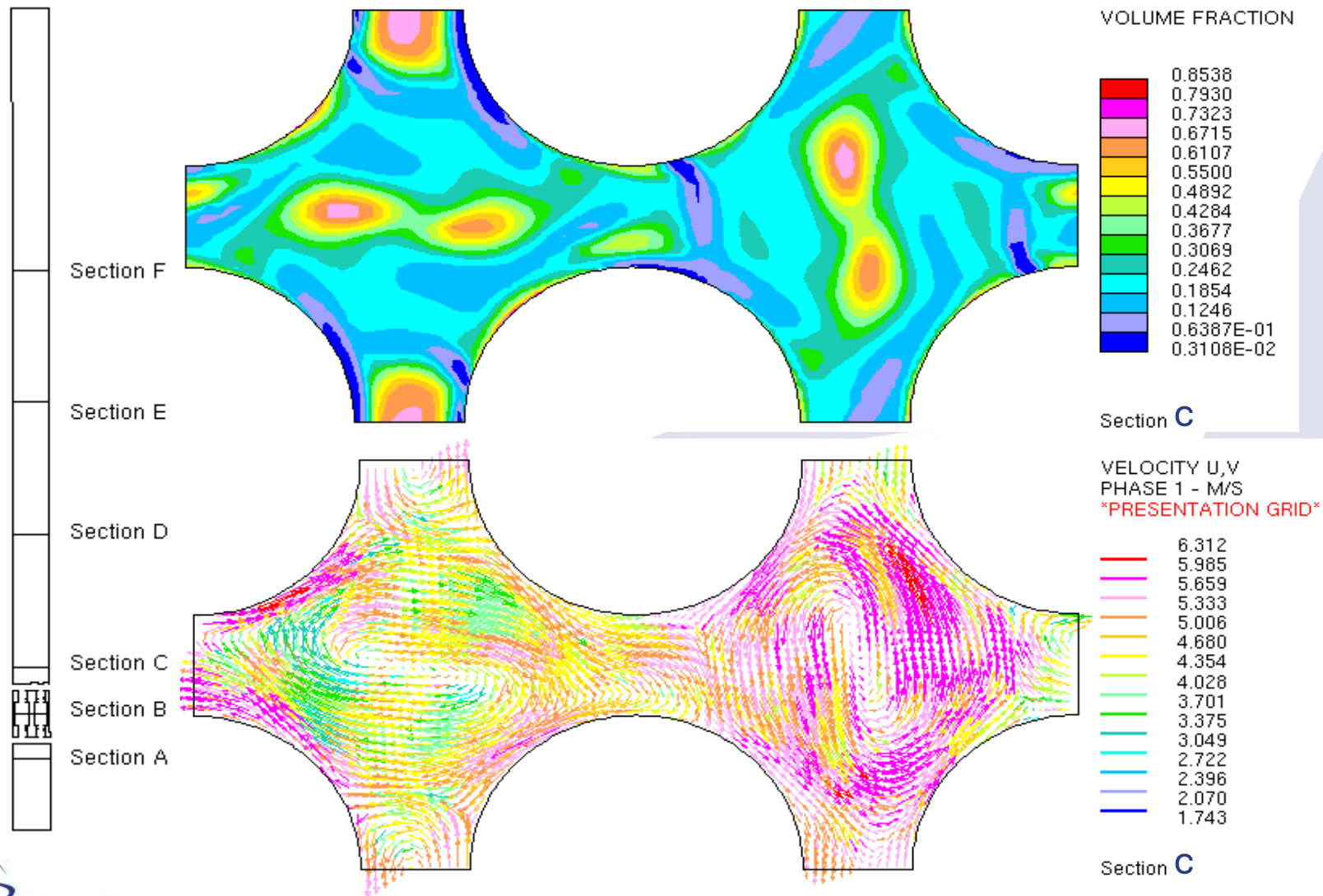
Void distribution

# Channels with spacer grid

- ~2.6 M cells (fine grid model)
- 2 channels with spacer
- Two-phase flow
- SUN: 8 processors with 900 MHz
- Steady-state calculations required ~1.5 days (not optimized)

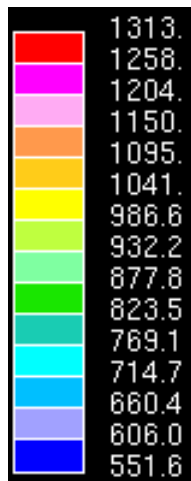


# Swirling flow and phase separation after spacer grid

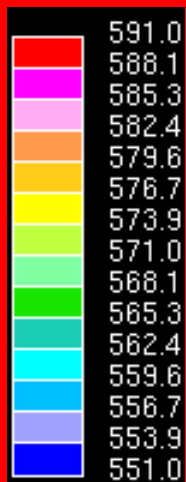


# Boiling conjugate heat transfer

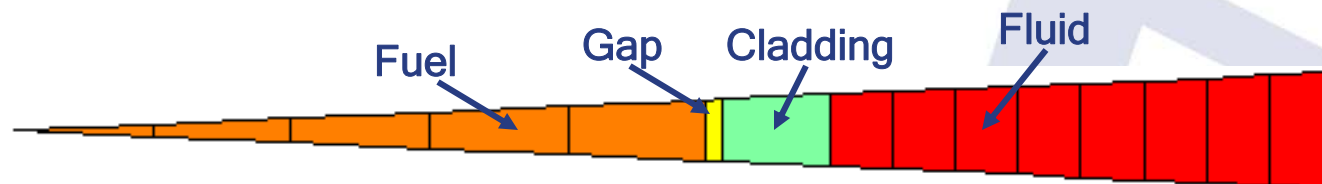
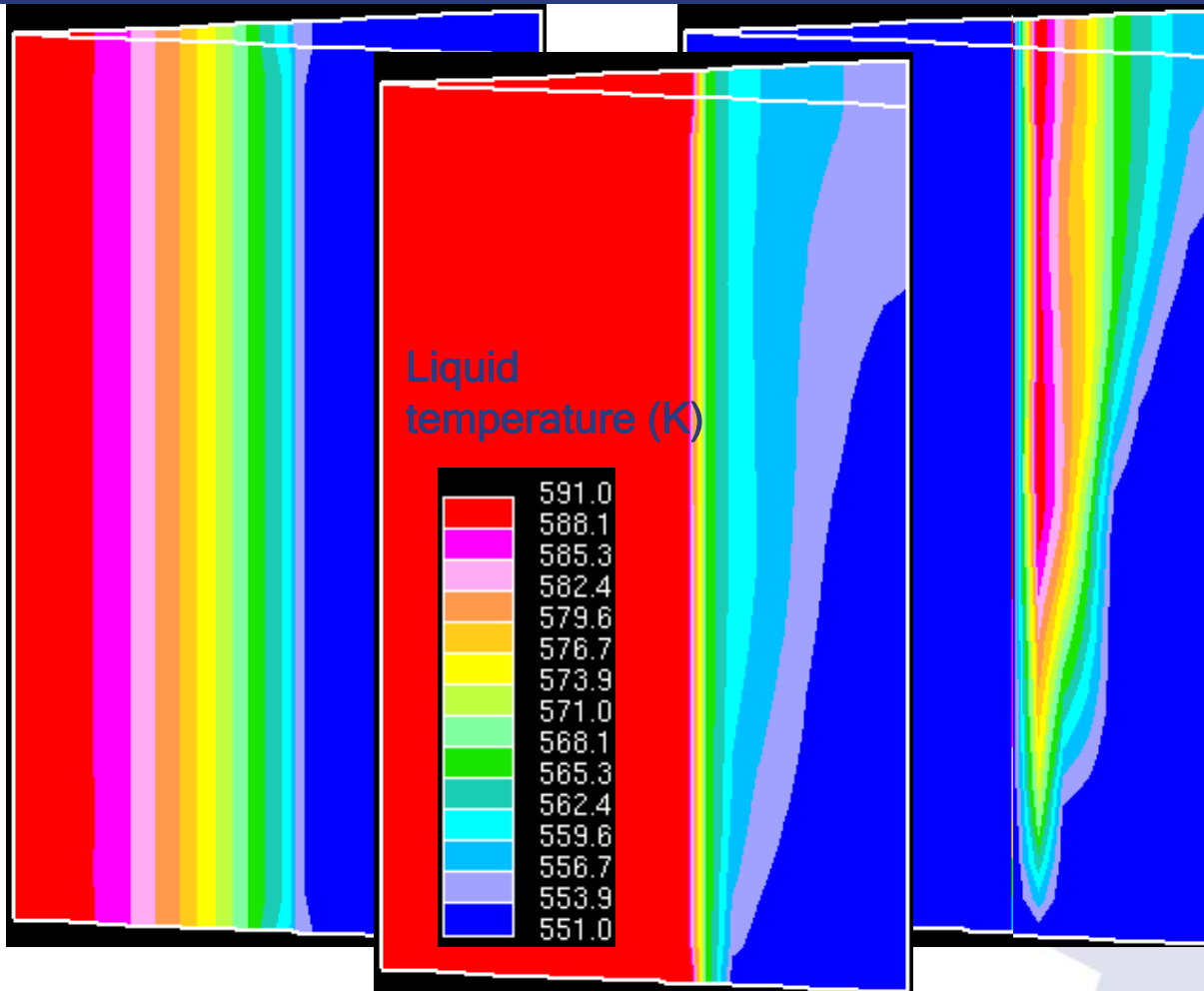
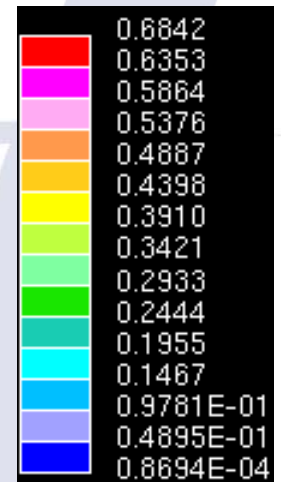
Soild temperature  
(K)



Liquid  
temperature (K)

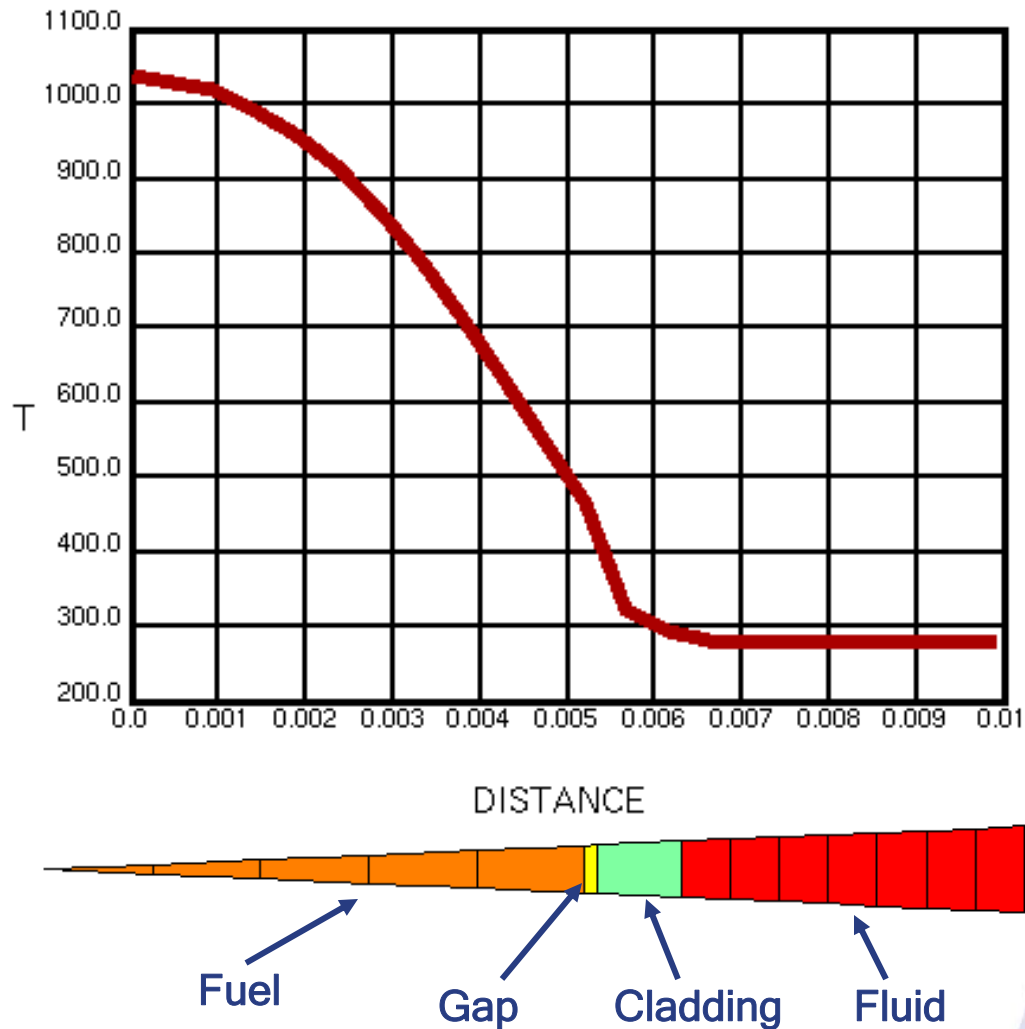


Void fraction

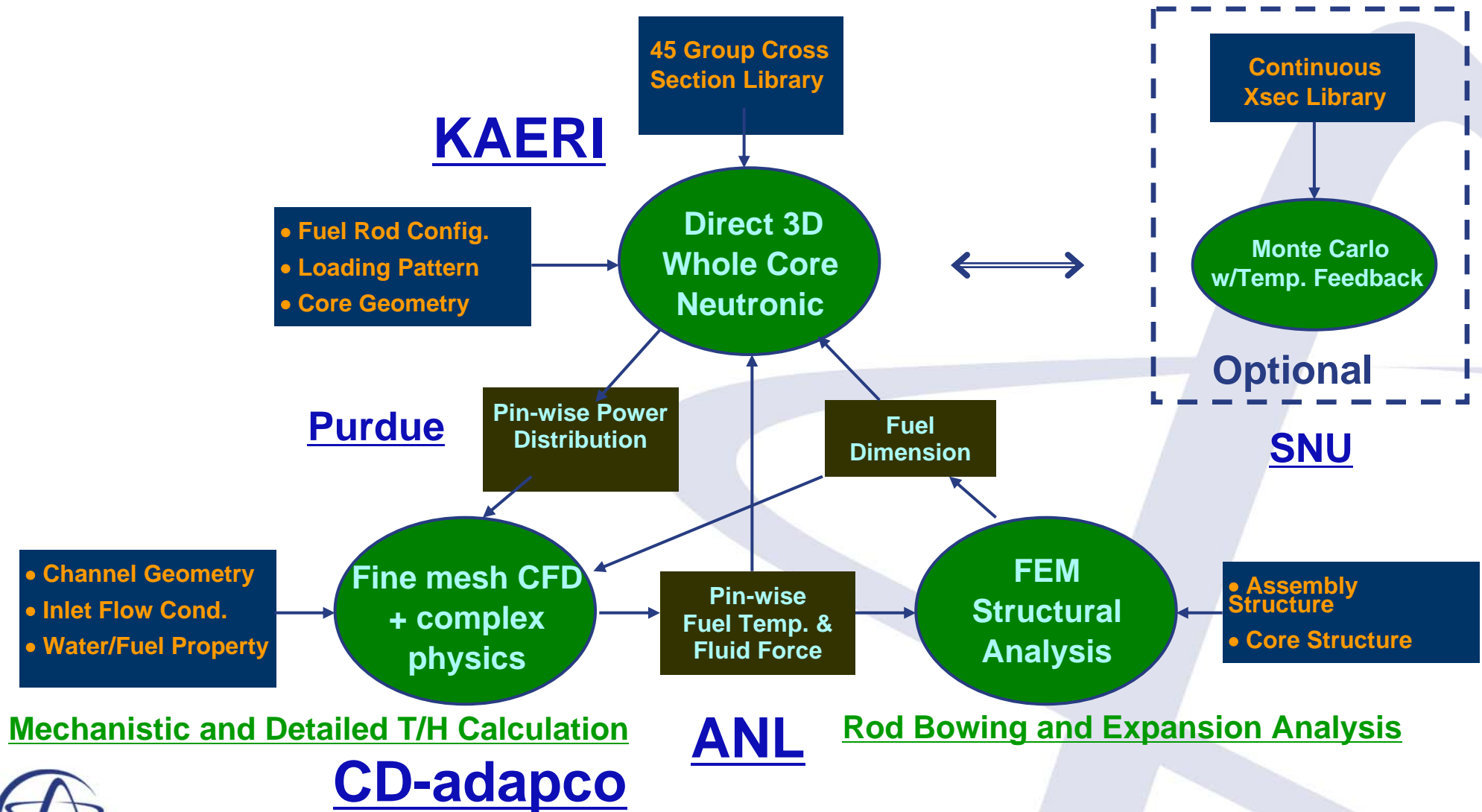


# Boiling conjugate heat transfer – Temperature profile

TEMPERATURE PROFILE ACROSS ROD AND FLOW

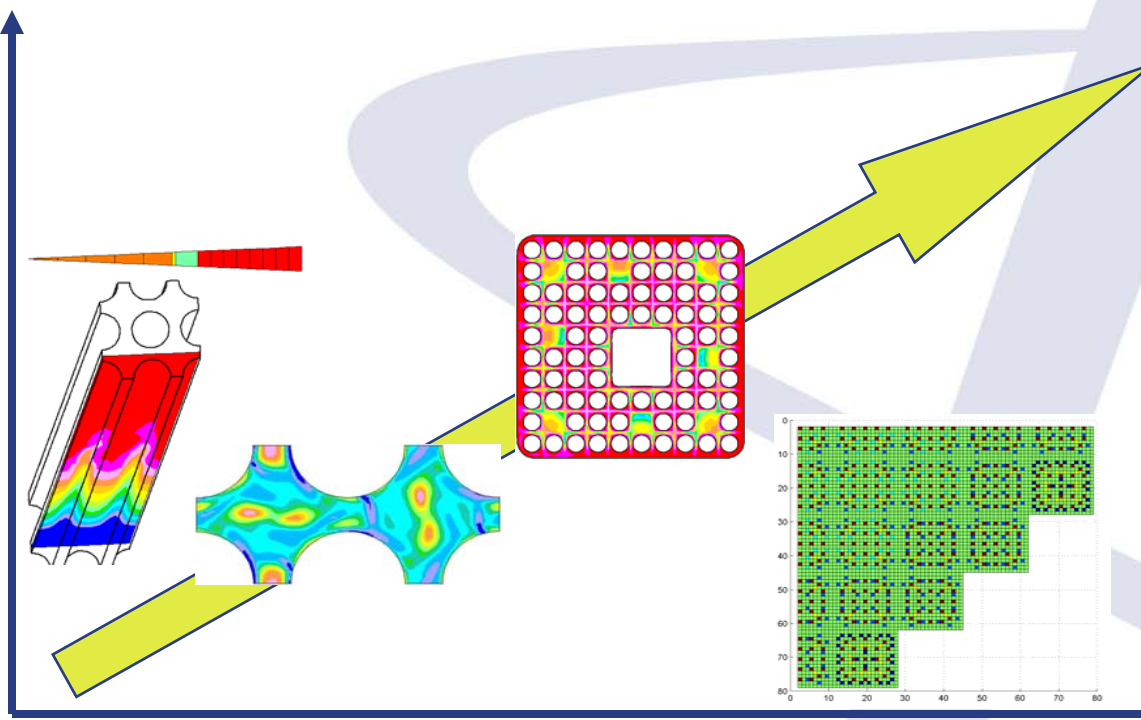


# Numerical Reactor Elements and Participants



# High end computing opportunity

- Opportunity: *realistic physics in realistic geometry*
  - Better resolution of geometry: multi-channels, spacer grids, whole core and beyond, ...
  - More completed physics: multiphase flows, boiling, conjugate heat transfer, neutronics, water chemistry, crud deposition, structural analysis, ...



# High end computing requirement

- Requirement: *high end software running in high end hardware*
  - Hardware: massively parallel computers, high speed communications, large memory, ...
  - Software: models for coupled physics, solution algorithms robust to cope with coupled physics, efficient to utilise massively parallel computers.

